throughout physiology.)[10] Schwann drew a parallel between cell formation and crystal formation. Even though the details of crystal formation were not yet known, it was clearly a mechanical process not requiring any vital forces, and this made it a very compelling model for Schwann. He proposed that a mechanism of attraction drew a particular kind of material out of the intercellular fluid, with each layer (the nucleolus, the nucleus, and the cytoplasm) drawing out different substances. He discounted the importance of differences between inorganic crystals and biological cells: "If crystals were formed from the same substances as cells, they would probably, in these respects, be subject to the same condition as cells" (Schwann, 1839/1947, p. 208; for further analysis, see Bechtel, 1984).

Schwann's commitment to chemical mechanisms for explaining vital phenomena was already manifest in his earlier research on digestion, in which he discovered pepsin, the first enzyme identified in animals (Schwann, 1836). In the eyes of some mechanists, Schwann's commitment to mechanism was compromised when, in 1837, he presented evidence that fermentation was a process requiring living yeast cells (Schwann, 1837). Many mechanists associated such a claim with vitalism. But Schwann did not see himself as embracing vitalism and in part III of *Microscopical Researches*, the book in which he introduced his cell theory, he returned to the topic of fermentation, presenting it as an example of the kind of metabolic phenomena exhibited in cells (Schwann here coined the term *metabolism*).[11] He proposed that the ability of living cells to carry out activities that would not otherwise occur in nature was due to the distinctive chemical constitution of cells that resulted from the process of cell formation, itself a mechanical process. The significance of Schwann's contribution was to fix the cell as the locus of control (Bechtel & Richardson, 1993, Chapter 3) of basic life functions such as nutrition.[12] He

[10] Müller's own position regarding vitalism was more ambiguous, but among his students many, such as Emil du Bois-Reymond, Ernst von Brücke, Hermann von Helmholtz, and Carl Ludwig, were outspoken advocates of a mechanistic physiology (see Cranefield, 1957).

[11] Schwann characterized a cell as having "the faculty of producing chemical changes in its constituent molecules. Besides which, all the parts of the cell itself may be chemically altered during the process of its vegetation. The underlying cause of all these phenomena, which we comprise under the term metabolic phenomena, we will denominate the *metabolic power*" (Schwann, 1839/1947, p. 197).

[12] Schwann's strategy basically was to argue that whatever activities cells perform would not be performed twice, once in the cell, then again in the whole organism: "Now, as all cells grow according to the same laws, and consequently the cause of growth cannot in one case lie in the cell, and in another in the whole organism; and since it may be further proved that some cells, which do not differ from the rest in their mode of growth, are developed independently, we must ascribe to all cells an independent vitality, that is, such combinations of molecules as occur in any single cell, are capable of setting free the power by which it is enabled to take up fresh